PROGRESS REPORT

Stanford U

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Title : Electrophysiological Correlates of Vigilance and Learning

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A BRIEF SUMMARY OF WORK AS OF SPRING, 1967

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The work of this laboratory is centered upon understanding neural mechanisms mediating human performance and perception, as studied by electrophysiologic techniques. Earlier work dealt with the relationship between spontaneous EEG rhythms (both pre-stimulus features and reactivity) and moment-to-moment fluctuations in vigilance and speed of simple response to visual stimuli (RT) (1-6). Automatic recognition techniques employing the LINC computer have been developed for some of the EEG parameters of interest, including period and amplitude analyses (7).

The correlation between simple reaction time and the averaged evoked potential has been established (8). Some experiments done collaboratively with Frank Morrell and John S. Barlow (the latter on a working visit to our laboratory) concerned such issues as the suceptibility to conditioning of evoked potentials, and the effects of different sets to respond and direction of attention (9, 10). A variety of evoked potential studies with polysensory stimuli, based upon the conditioning paradigm have been done (one series in collaboration with E. Roy John)(7). Various extensions of evoked potential analysis have been employed in studies of patients with focal cortical lesions (7, 11, 12).

Much of the above has been regarded as preliminary, geared to establishing some elementary EEG-behavior relationships and developing the necessary laboratory techniques and computer programs.

In the last year, investigation has centered on temporal parameters of sensory interaction as studied simultaneously by behavioral and electrographic means (13, 14). This work has been motivated by two lines of inquiry which for the most part have not been related to each other:
(1) Various studies in experimental psychology showing that polysensory stimuli modify behavior and perception with respect to a signal in a given sense mode (15-17); (2) Newer electrophysiological studies including both the beautiful observations of polysensory convergence at single neurons (with exquisite encoding possibilities in the unique temporal patterns of cell response) and the unit and evoked potential demonstrations of polysensory facilitation and inhibition (18-23). Several series of experiments are now complete, which are similar in format to that reported by Helson (17). We found that an auditory stimulus coming after a visual stimulus to respond has a facilitating effect upon visual RT, an effect which tends to decrement linearly with interstimulus interval. The range investigated was 20-120 msec. One series involved a random presentation of flash-click pairs at various interstimulus intervals and occasionally flash alone (a variant of the a-reaction since every trial contained the "go" visual signal). Another used choice RT of the classic c-reaction type; occasionally click alone is presented and response is to be withheld. The addition of choice led to essentially similar results, in fact, even more consistent.

Parallel enhancement of evoked potential (EP) amplitudes (and reductions in latency) were noted as a function of interstimulus interval. The EP effects were most consistently observed in transverse bi-polar arrays rather than anterior-posterior arrays, and for left motor cortex more than right homotopic motor leads. (All subjects were right-handed and all responded with the right hand.) In order to clarify the manner in which the polysensory evoked potential was derived, two-way linear regression analysis was applied to the electrographic data. The method involves analysis (reiterated for each polysensory average for all electrode derivations) of three waves obtained from the subject in the course of the randomized presentation series of a given experiment: EP to flash when presented alone, EP to click when presented alone, and the compound EP to a flash-click pair at a particular interstimulus interval. Using least squares methods, we solve for the co-efficients to be applied to the flash evoked wave and the click evoked wave in order to best approximate the obtained compound wave by a linear model. (i.e., (x) light + (y) click = obtained compound wave; appropriate time displacements are made for each analysis.) Some of the findings to date are: (1) A linear model accounts for substantial portions of the variance of the compound evoked potential. Values range between 50-95% depending upon such factors as electrode placement, interstimulus interval, and the components included in the analysis. (2) Linearity is more characteristic of those cortical recording fields in which the most systematic amplitude effects were noted (especially contralateral motor cortex). (3) Linearity is also more characteristic of the shorter interstimulus intervals. (4) Simple summation does <u>not</u> appear to characterize the polysensory wave form in the great majority of cases. The regression co-efficients for both light and click (x and y) most often differ significantly from 1.0. These findings are thus at considerable odds with Grey Walter's concept of idiodromic projection to cortex of the different sensory afferents (24), which he stated would lead to simple summation in the polysensory case.

It would seem of interest to study the "refractory period" phenomena, described by Fraisse (25) and reported by Davis at Oxford (15) to hold for the polysensory case, with these same methods. In those studies, the subject is instructed to respond to the second of two closely spaced signals. If the delayed RT's are replicated, then analysis of the evoked potentials ought to clarify whether these wave forms are intimately connected with the signal processing. However, I. D. John, an Australian, has found facilitative effects instead of response delay in the "refractory" model experiment (26).

Some pilot studies on simultaneity-successivity judgments in the bisensory situation have also been done in our laboratory. The temporal characteristics of perceived simultaneity are in agreement with the RT facilitation function. We are also curious about possible brightness enhancement effects in the polysensory situation; there have been a number of recent reports wherein extraneous visual stimulation shifted the auditory generalization gradient (16). We have also been doing some pilot work with metacontrast and blanking phenomena in vision and investigated the effects of using more than two stimuli in close succession. From Robinson's note in Science (27), it seems that masking effects can be "undone." We have seen the same thing with appropriate stimulus parameters. Somewhere on the agenda is a study of the evoked potentials related to these various perceptual phenomena, in spite of the cooling effects of Schiller and Chorover's observations (28).

Even in the context of an experiment in which clear-cut effects of stimulus parameters are to be found (as in the sensory interaction studies), it seems fruitful to understand the features of intra-individual variability.

We are now following these working hypotheses: The evoked potential waveshape, particularly as recorded from the contralateral motor cortex in a setting in which motor response times are measured, may be regarded as the statistical distribution in time of the degree of synchrony of the neural population in the recording field of the electrodes. The evoked potential may be assessing decision and "readout" processes in addition to sensory input. We have observed that when the EP assumes a relatively leptokurtic shape, the associated distributions of RT's to the same stimuli on the same trials as those from which the averaged EP is based are of low variability and often sharply skewed. If, for a given input, an "M" shaped late wave appears in the EP, the distribution of associated RT's tends to have higher variability and to be somewhat bi-modal. Sub-averaging of trials associated with each part of such a distribution reveals that the averaged EP on the fastest RT trials is single-peaked with a relatively early latency; for the slowest RT trials, a single peaked evoked potential of longer latency appears. In instances of RT distributions of great variability and many modes, the EP waveshape is consonant (dispersed in time, flattened, with many low amplitude peaks). This work is still actively in progress, but we are excited about its possible implications. It emerged from the sensory interaction work. Looking over the older simple RT data, it seems a good approximation. The latencies of these correlated peaks in the EP's fit very well the period just prior to "decision" to respond, about 100 ms before the button is pushed. Evart's recent work on pyramidal tract neurons seems consonant with this line of thought. We plan to continue to explore this area and learn more about the organization of motor responses,to study EMG in the relevant arm, and also EP's associated with voluntary movements in the absence of particular "go" signals.

In summation: it appears that the complex evoked potential waveshape recorded in response to afferent stimulation in the performing subject may contain measures of neural activity both relatively early (recognition processes) and late (decision processes) in information handling. It seems useful to try to pursue the analysis of these electrical signs of information processing by experiments on two fronts. The perceptual studies suggested above (e.g., simultaneity judgments in the polysensory case) should enable delineation of components linked to such functions as temporal resolution of stimuli; the further study of relationships with reaction times may indicate the topography and time course of electrical activity associated with decision and motor processes.

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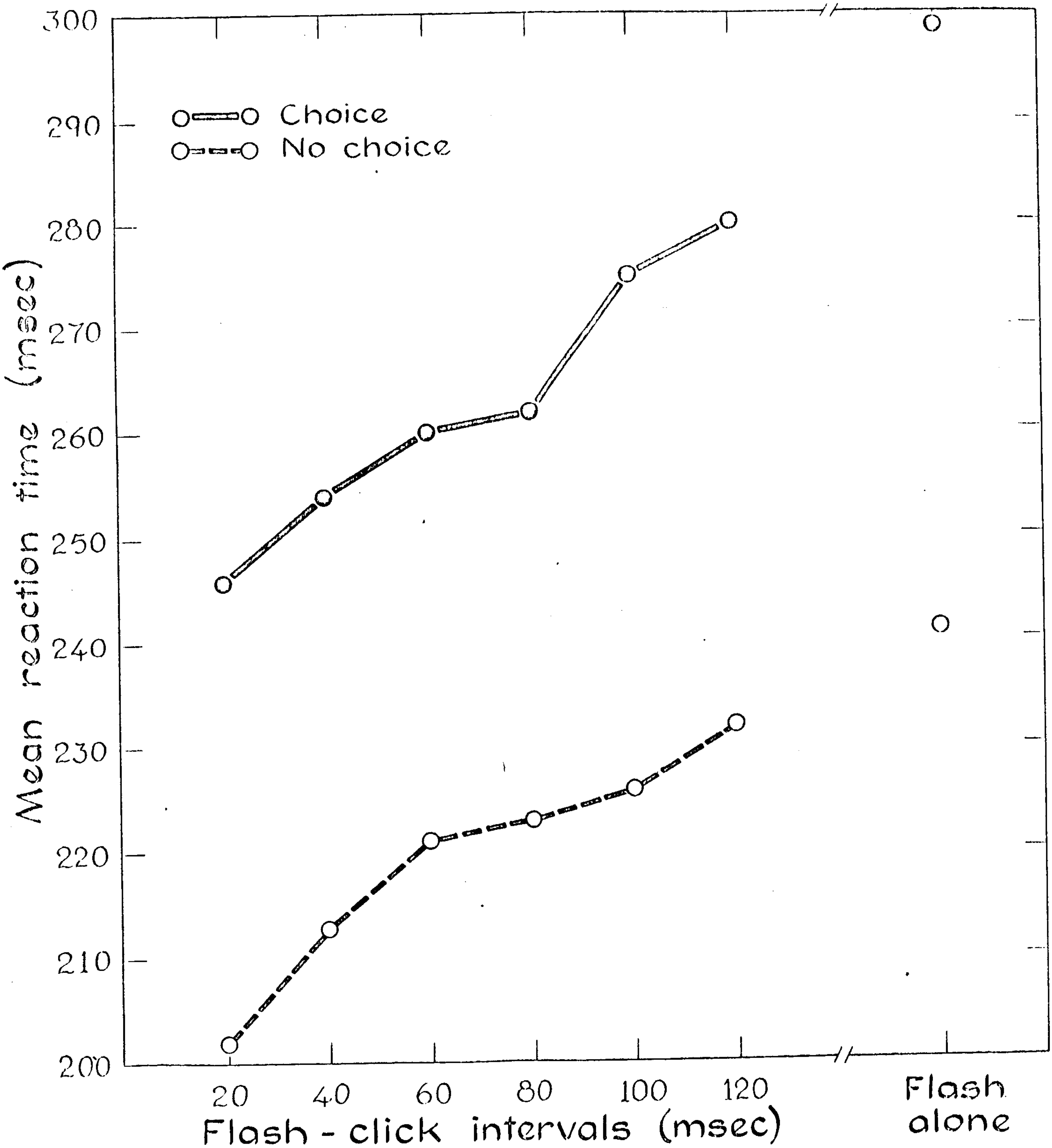
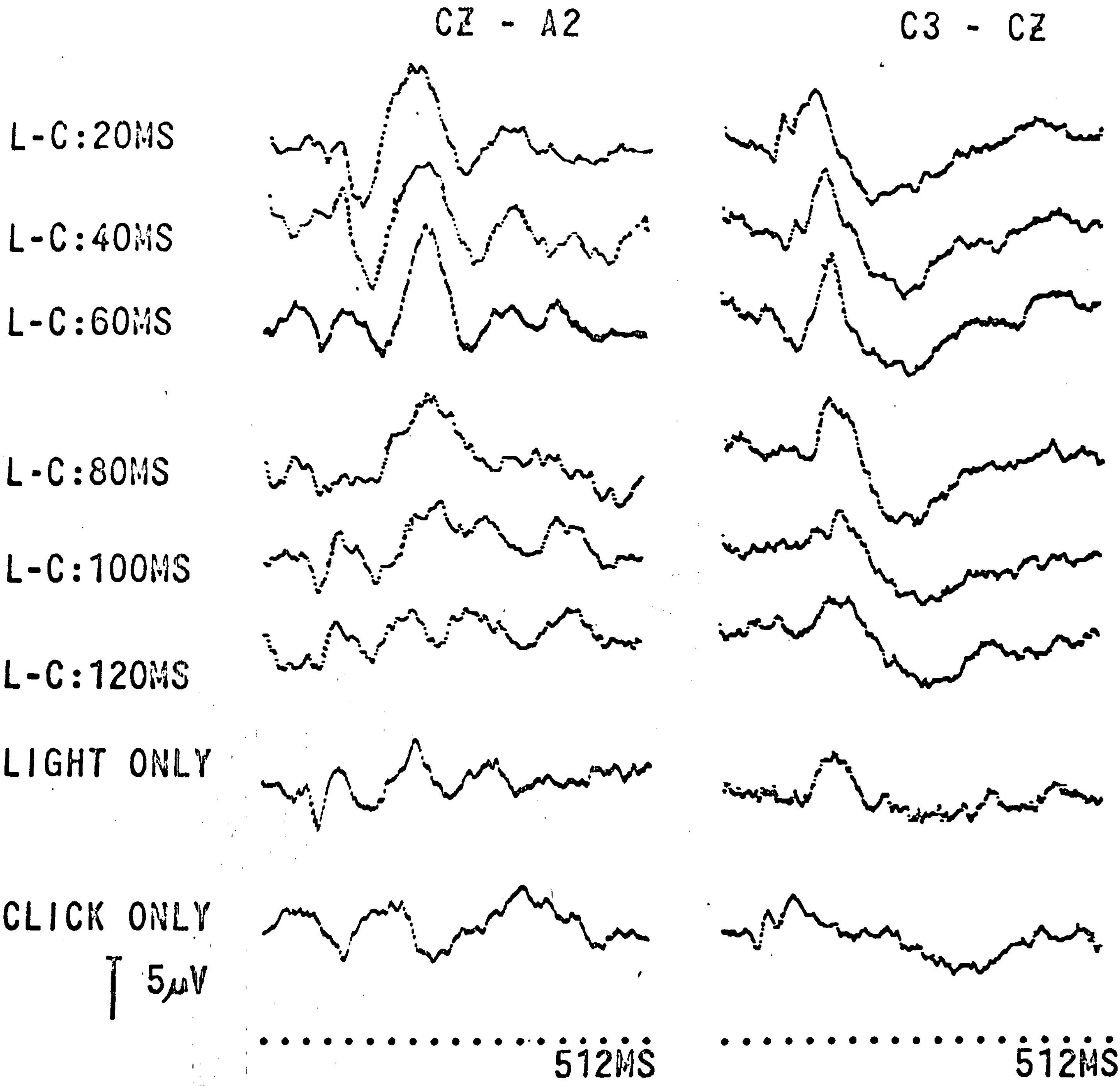
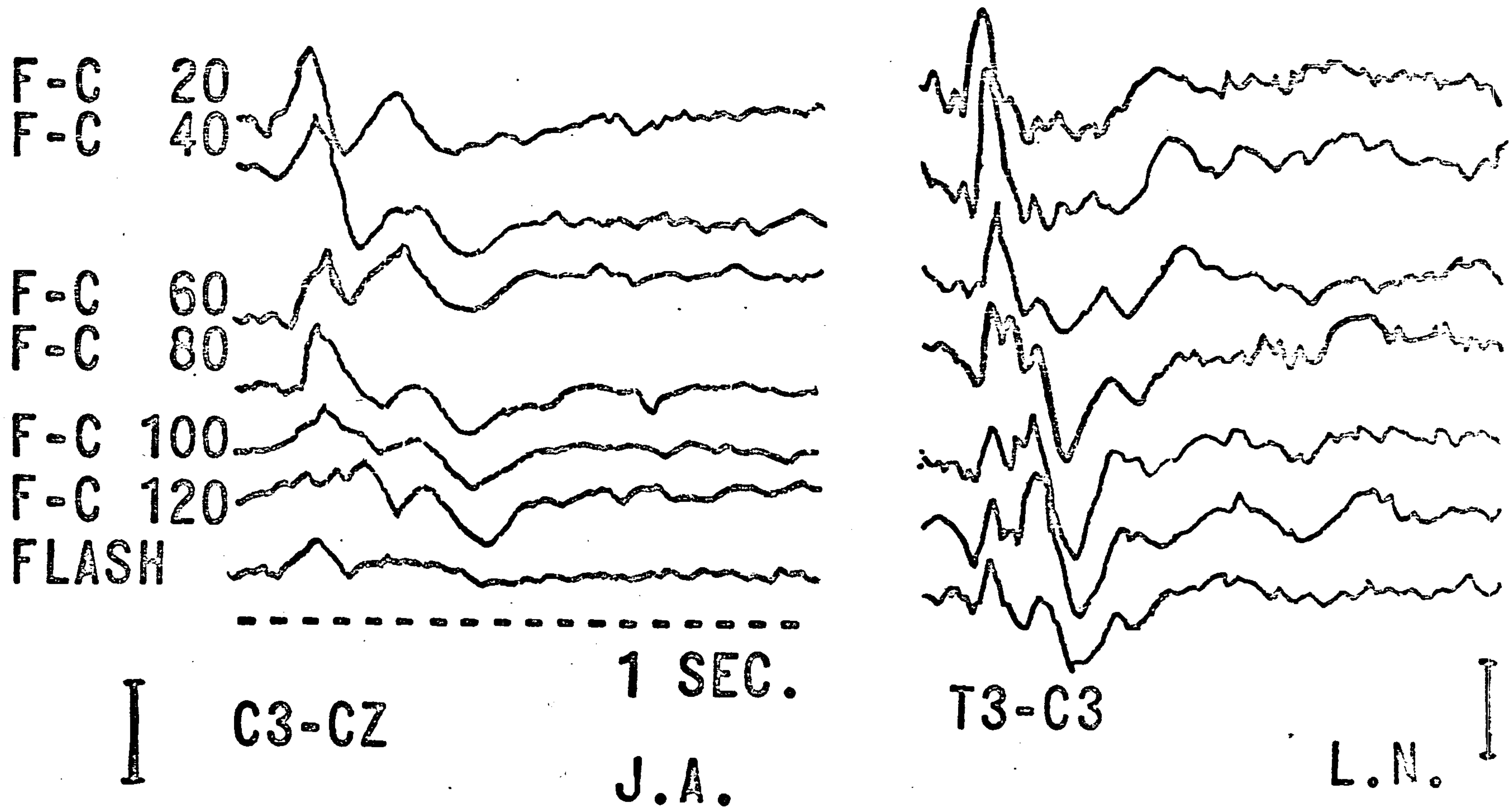
Papers in preparation.

1. Temporal characteristic of sensory interaction in choice reaction times.
2. Comparison of the effect of auditory extra-stimuli upon visual reaction times with that for visual extra-stimuli upon auditory reaction times.
3. Temporal parameters of sensory interaction: Evoked potential observations in man.
4. Linear regression analysis of polysensory evoked potentials.
5. A simple EEG amplitude predictor of response failure in vigilance tasks.
6. Period analysis of the EEG and prediction of speed of response to visual signals.

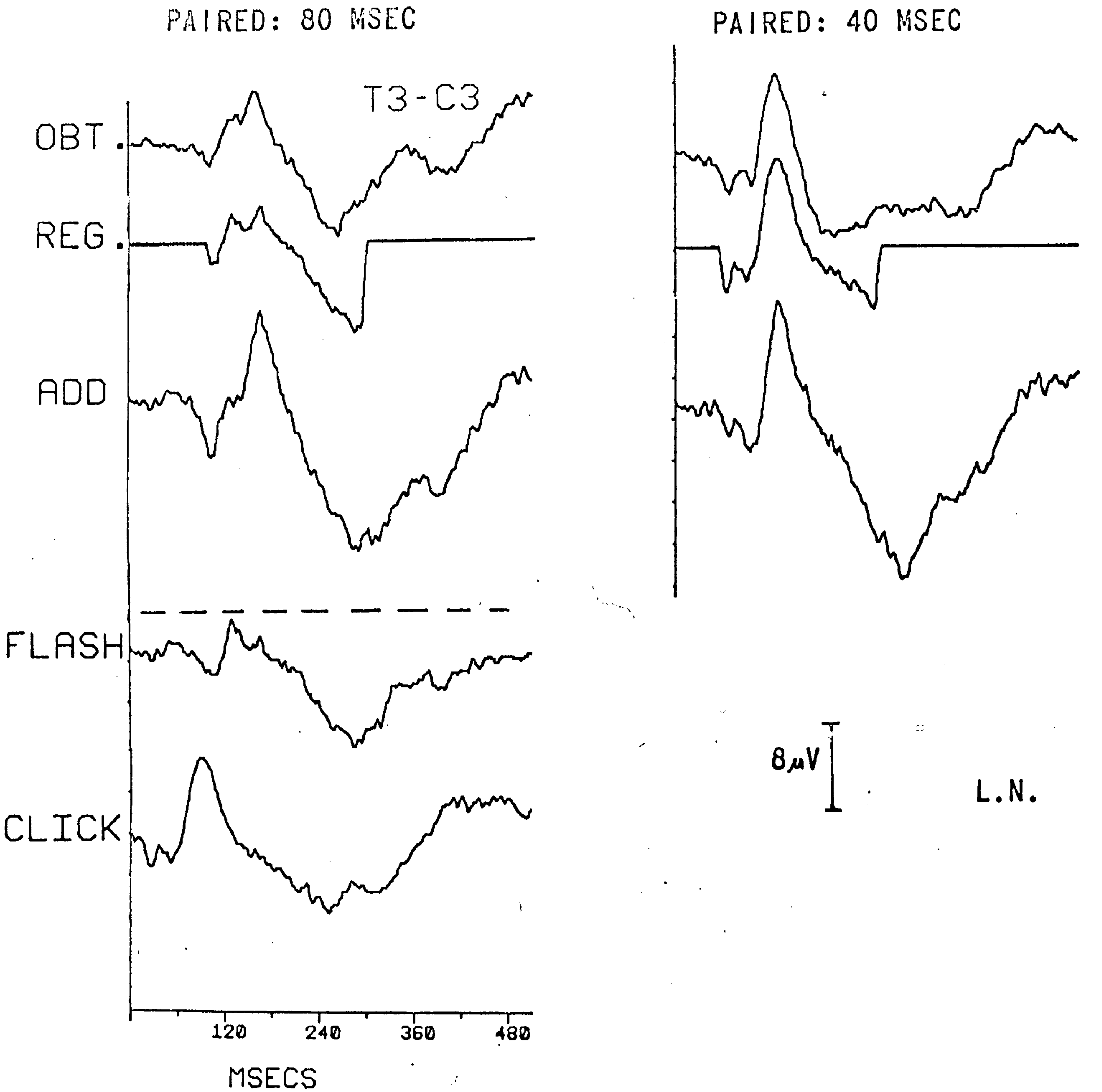

Choice
No choice
Mean reaction time (msec)
300
290
280
270
260
250
240
230
220
210
200
20
40
60
80
100
120
Flash alone
Flash - click intervals (msec)



Averaged evoked responses to flash-click pairs at various interstimulus intervals, and to flash and click presented singly. Records from two different subjects in choice RT experiments.

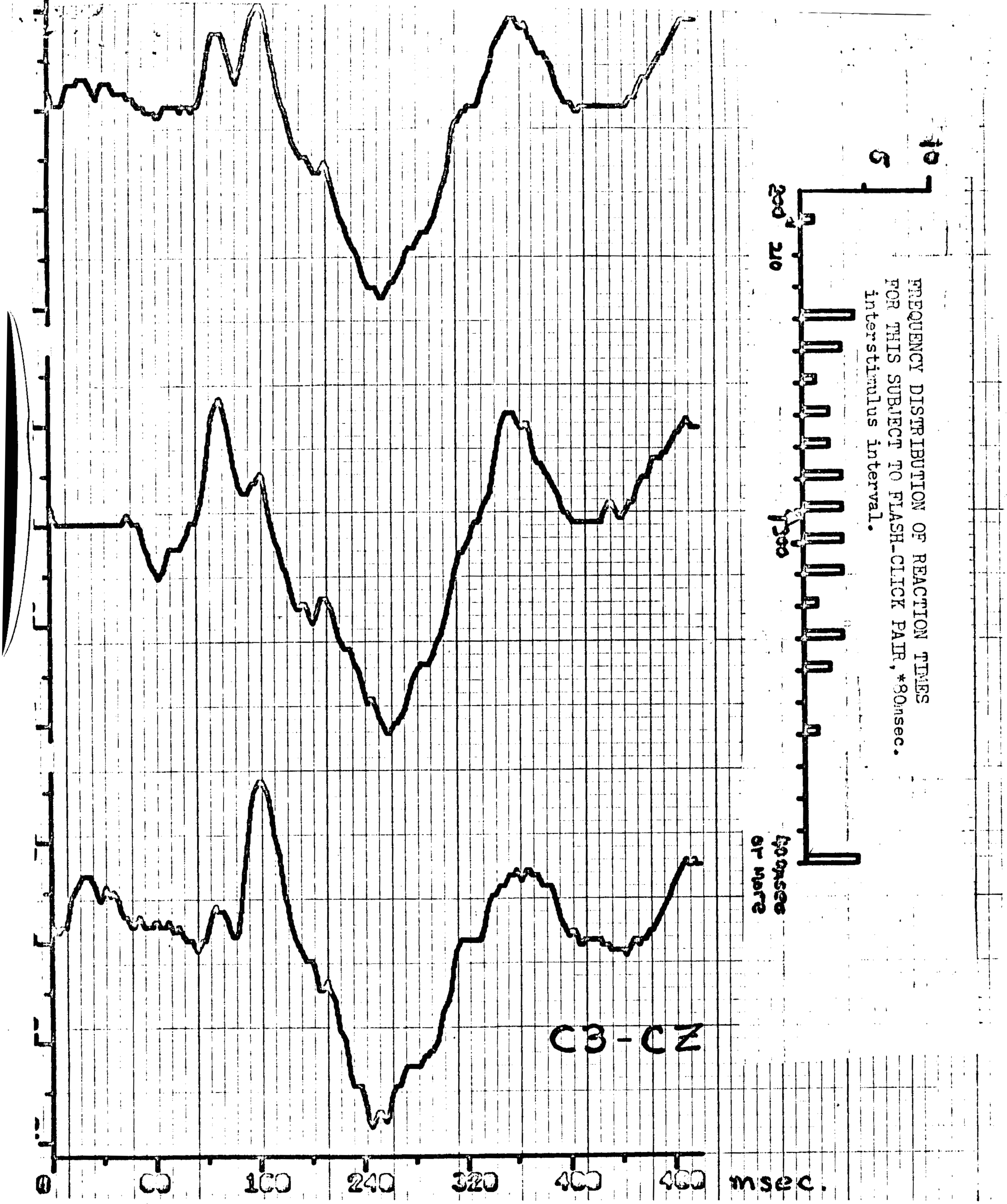


Averaged evoked responses to flash-click pairs at various interstimulus intervals; response to flash alone. Records from two different subjects in experiments in which the subject responded on every trial.



Averaged evoked responses to flash-click pairs from subject in choice RT experiment.

Obt. = obtained response. Reg. = waveform created from linear regression analysis; non-zeroed portions were used for analysis. Add = waveform created by simple addition, with appropriate time displacement of the obtained response to flash (shown in fourth tracing from top) and click (fifth tracing) when these were presented singly.



Averaged evoked potentials, recorded from C3-Cz to flash-click pair separated by 80 msec. interstimulus interval. Top: average based on all 36 trials which were given at random in the course of experiment for this interval. Center: average based upon the subset of these trials to which the fastest manual responses were given. Bottom: subset for the slowest manual reactions. Division point indicated in the associated frequency distribution along the side. Sweep: 500 msec. Note